Energy efficient self-build homes

- How two families built very different low-energy homes
- Putting together a balanced specification
- Technical information and advice

GOOD PRACTICE GUIDE 365

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

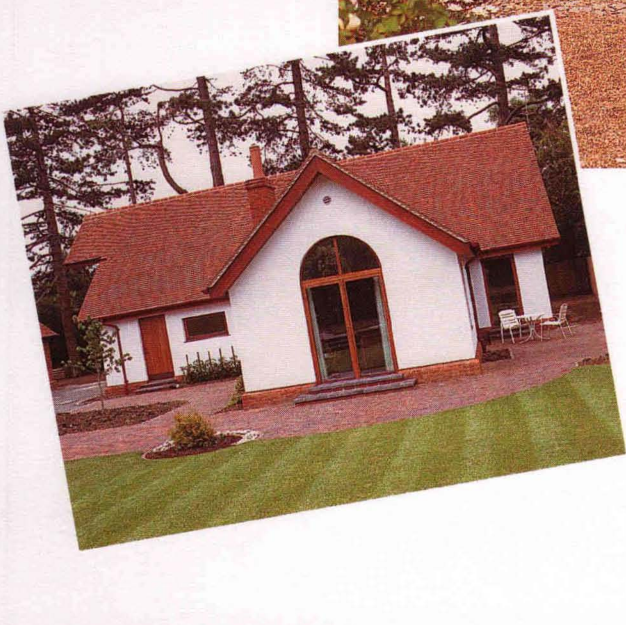
BEST PRACTICE PROGRAMME

INTRODUCTION

Building an energy efficient house (or having one built) is not difficult. Achieving energy efficiency simply requires some care and attention throughout the project, from inception to completion. It involves:

- appointing a designer who is experienced in energy efficiency
- developing a design which combines a well-insulated construction with an efficient and appropriate heating system
- specifying appropriate heating and ventilation equipment
- careful briefing of builders and other tradespeople during the course of the construction, finishing and fitting-out.

This Case Study describes the approaches adopted by two couples who set out to build their own energy efficient homes. The resulting houses, although quite different, are comfortable to live in and economical to run.



THE STONES' HOME, MILTON KEYNES

THE STONES' HOME, MILTON KEYNES

Mr and Mrs Stone's timber-framed house has enhanced levels of insulation and a very efficient and responsive heating system. It avoids the use of expensive features such as mechanical ventilation and heat recovery (MVHR) or high performance glazing, yet it achieves a good energy rating and low carbon dioxide (CO_2) emissions.

This was the Stones' second self-build house, and although low energy use was not an initial priority, they wanted to build a comfortable house with low running costs. They wanted an individual design, so an architect was appointed to develop their initial design ideas into detailed plans and, because they did not live close to the site, he was retained to manage the build. Planning permission was not a problem, and for reasons of speed the house was built by a contractor (appointed after a traditional tender), using a purpose-designed timber frame.

The aim was to create a well-insulated envelope, and provide an efficient heating system. The Stones were familiar with the timber frame technique from their first self-build home, and were keen to use it again. This was reinforced by the need for a short construction period.

The architect was aware of the insulating possibilities of timber frame construction. (Extra insulation can easily be accommodated in the walls and roof.) However, he felt that to complement a lightweight structure such as timber frame it was important to specify a responsive heating system that reacts quickly when heating is turned on or off. This helps to prevent overheating in well-insulated houses of limited thermal capacity, such as this. Consequently a radiator system was installed which was heated by a gas-fired condensing boiler and controlled by a sophisticated programmer, room thermostat and thermostatic radiator values.

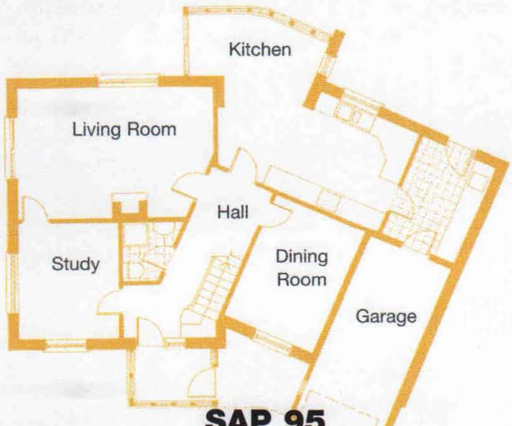
The Stones decorated the house themselves, and carried out most of the landscaping. After two years of occupation they have found the house warm and economical to run in winter, although some of the highly glazed spaces do tend to overheat slightly in summer.

SHEILA AND ALAN STONE

When Alan Stone retired, he and his wife Sheila decided to build a new house in Milton Keynes, near to Sheila's place of work. They built a 2060 sq ft (192 m^2) four-bedroom detached house at a cost of about £120 000. The house is of timber-framed construction, with an integral garage, and is located on a serviced plot specially provided for self-builders.

The house has:

- 140 mm thick mineral wool insulation in timber frame walls, clad with brickwork (U-value 0.2 to 0.29 W/m^{2}K)
- 200 mm thick mineral wool insulation in the loft (U-value 0.21 to 0.32 W/m^{2}K)
- a ground floor of pre-cast concrete beams with polystyrene infill blocks and a concrete screed (U-value 0.14 W/m^{2}K)
- hardwood casement windows with standard double glazing (U-value 3.3 W/m^{2}K)
- a gas-fired condensing boiler, supplying heat via radiators
- a boiler programmer with weather compensation, a room thermostat and thermostatic radiator valves
- a standard factory-insulated 200-litre hot water storage tank.



SAP 95

CO_2 emissions 42 kg/m^2

THE EMBLETONS' HOME, TWYFORD, BERKSHIRE

JOYCE AND MIKE EMBLETON

Joyce and Mike Embleton set out to build an energy-efficient, three-bedroomed bungalow with a basement and garage on a constricted, in-fill site close to Mike's job. For £200 000 they built a 1520 sq ft (141 m^2) house with an additional 800 sq ft (74 m^2) of space in the basement, 680 sq ft (63 m^2) in the loft, and a 390 sq ft (36 m^2) garage. The house is of insulating formwork construction.

THE EMBLETONS' HOME, TWYFORD, BERKSHIRE

This is a highly insulated house with an unusual form of wall construction. It has a condensing gas-fired boiler serving an under-floor heating system. Attention has been paid to reducing air infiltration, thus allowing the mechanical ventilation and heat recovery (MVHR) system to function effectively. The Embletons appointed a local architect to convert their ideas into designs and, because of planning complications, to deal with the submission of a planning application. As energy efficiency was a priority, the architect suggested that an energy consultant also be appointed.

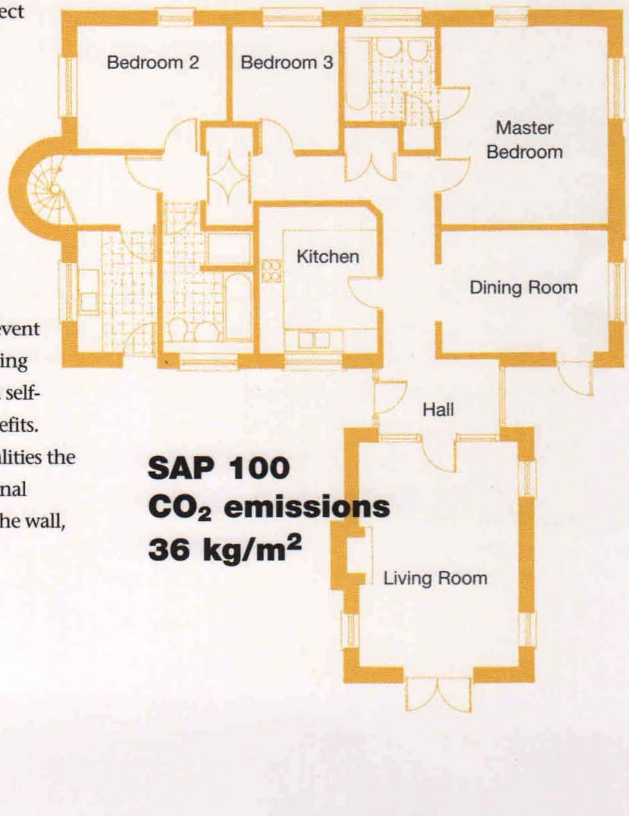
A well-insulated envelope was required, and initially the Embletons considered using a timber frame construction method. The architect and energy consultant preferred traditional masonry construction with large cavities filled with insulation, because this provides more thermal capacity and helps prevent overheating. Mike Embleton then saw insulating formwork wall construction (see glossary) at a self-build exhibition and was persuaded of its benefits. Although this system has good insulating qualities the energy consultant recommended that additional insulation should be added to the outside of the wall, with a rendered finish.

The Embletons had previously owned a condensing boiler, and appreciated its energy saving potential. They decided to combine its benefits with an underfloor heating system because the low return water temperature of such a heating system maximises the efficiency of this type of boiler.

Underfloor heating systems can be unresponsive (see box opposite). However, this was not expected to be a problem in the Embletons' home because the house has a high thermal capacity and allows the structure to absorb unwanted heat gains.

Several contractors tendered to build the house but because the prices submitted were high it was decided to appoint individual tradesmen to carry out various parts of the work. The Embletons took on the management of this process themselves, giving them greater control of the building work. The house was built to a very high specification, with expensive finishes, and includes several additional energy saving measures.

The MVHR system was specified because the Embletons were familiar with its potential benefits. The system installed recovers about 60% of the heat from expelled air and creates a pleasant, odour-free environment. Its potential in saving energy is only realised because they took steps to



SAP 100
CO_2 emissions
36 kg/m^2

THE EMBLETONS' HOME, TWYFORD, BERKSHIRE

HEATING SYSTEMS: THE IMPORTANCE OF EFFICIENCY AND RESPONSIVENESS

It is important for a dwelling to have both an efficient and a responsive heating system, and to use the most cost-effective fuel. Any heating system that involves storage of heat, whether in heat emitters such as storage heaters, or in the building fabric (as in underfloor heating) will be slow to respond to changes in heat demand. This can result in both wasted energy and a tendency for the dwelling to overheat, particularly in well insulated, lightweight buildings. A heating system's responsiveness can be improved by providing better controls. A programmer and thermostatic radiator valves (TRVs), or individual room thermostats, are the minimum recommended. In some cases 'zone controls' (separate time and temperature control of heating serving upper and lower floors of a house) may be appropriate.

ensure that the envelope of the building is very airtight (see box below). They have found the house comfortable, and enjoy the gentle warmth of the floor, although they would sometimes enjoy a feature source of heat, particularly after coming in from the cold.

An MVHR system is most effective if the house has a very low background air infiltration rate. Air leakage tests by fan pressurisation are useful in assessing the airtightness of the envelope and identifying any leaks. The Embletons found that air leakage was only 2 ach (air changes per hour) at an air pressure of 50 Pascals (compared with a typical figure of about 8 to 10 ach). This equates to a very low 0.1 ach at normal air pressures, and means that the MVHR system can function effectively.

The house has:

- walls of 160 mm thick concrete between two layers of 50 mm thick insulating polystyrene formwork, with additional external insulation, to give a total of 175 mm of insulation (U-value 0.19 W/m^{2}K)
- dense concrete blockwork internal walls to increase thermal capacity
- high-performance, side-hung, timber window frames incorporating factory-fitted, argon-filled triple glazing with low-emissivity glass (U-value 1.40 W/m^{2}K)
- hinged 'French doors' rather than sliding patio doors, to improve draught-proofing
- two layers of 75 mm thick extruded polyurethane roof insulation with metal foil on both sides (U-value 0.18 W/m^{2}K)
- pre-cast concrete beam and block ground floor with 50 mm thick expanded polystyrene below the screed (U-value 0.20 W/m^{2}K)
- a gas-fired condensing boiler providing heat to an underfloor heating system
- a 210-litre hot water storage tank installed in a purpose-made cupboard filled with insulation
- an MVHR system
- low energy light fittings.

ENERGY EFFICIENCY FEATURES

BUILDING ENVELOPE

An energy efficient house needs both an efficient heating system and a well-insulated and airtight envelope or shell (ie the walls, windows, floors and roof). The Embletons' house has high levels of insulation in the walls, and high-performance glazing (which loses less than half the heat of a conventional double glazed window).

Double glazing is now standard in most new homes. High-performance glazing, including 'low-emissivity' glass, is cost effective because a standard double glazed window will lose ten times more heat than an equivalent area of well-insulated wall. Argon-filled units and even triple glazing may also be worth investigating.

Good wall insulation can easily be achieved in 140 mm stud timber framed (or steel framed) houses like the Stones' house, or using more recent construction methods such as the insulating formwork used by the Embletons. Alternatives include traditional cavity walls with at least 4-inch cavities (up to 10-inch cavities have been built in the UK), or a solid blockwork wall with external insulation and a rendered finish. Wall U-values below 0.2 W/m^2K are now achievable.

HEATING SYSTEM

An often overlooked component of a successful low energy house is an efficient and appropriate heating system. Both houses in this Case Study are heated by gas-fired condensing boilers that can reach seasonal efficiencies of over 90% (compared to conventional boiler efficiencies of 60% to 75%). A condensing boiler is more expensive, but the payback period is usually only a few years, and will produce net savings for the rest of its life.

The choice of heat distribution system depends on the structure of the house. The Embletons chose underfloor heating, which is attractive to those who wish to avoid radiators, but responds slowly to changes in heat demand. Such a system can work well in heavyweight houses such as theirs, because the thermal capacity of the building will help absorb unwanted heat gains. In lightweight structures a more responsive heating system is appropriate and for this reason the Stones chose more conventional radiators controlled by an intelligent programmer, a room thermostat and individual thermostatic radiator valves. This provides good control, and when heat gains arise from the sun or from occupants' activities, heat output is reduced, saving energy and preventing overheating.

VENTILATION

Traditionally, houses have effectively relied on infiltration through cracks in walls, floors and the roof for fresh air, but this uncontrolled ventilation can waste energy. Best practice now favours 'build tight and ventilate right'. Modern building methods can reduce infiltration, and this saves energy, but it is necessary for the builder to pay particular attention to detail during construction, and seal all air paths as far as possible. Providing controlled ventilation then becomes important to prevent condensation and poor air quality.

The Stones adopted the conventional route of providing small trickle ventilators in the heads of the window frames, and electric fans to extract stale air from the kitchen and bathrooms. An alternative to this is passive stack ventilators which replace the electric fans with vertical ducts using the natural stack effect to remove warm, moist air from wet areas. These save the energy cost of operating electric fans.

The MVHR system that the Embletons installed ensures a steady air change rate, and recovers about 60% of the heat from extracted air, thus saving heating fuel. It does, however, use electricity to operate the fans, which reduces the savings in energy and fuel costs. The main benefit of MVHR is in maintaining good air quality within the dwelling. The Embletons were convinced of its merits when they noticed how well it cleared cigarette smoke.

GLOSSARY

GLOSSARY

U-value

The U-value is a measure of the insulation value of part of a building – the lower the U-value the better. The Building Regulations specify maximum U-values for the walls, windows, roofs and floors of a building.

Condensing boiler

This type of boiler has a larger heat exchanger which recovers more of the heat from the waste flue gases. It is therefore more efficient than conventional boilers in all circumstances. It is most efficient when the water returning from the heating system is relatively cool, as with underfloor heating.

Insulating formwork construction

Insulating formwork construction is a generic term for wall construction in which lightweight expanded polystyrene (EPS) blocks or panels lock together to create hollow permanent formwork which is then filled with concrete. The EPS block system used for the Embleton house is one of several such systems that are available in the UK. They are generally imported from Europe where they have been used since the 1970s, particularly with self-builders, because they are easy to use and do not require traditional building skills. They also provide a relatively easy way to achieve good wall insulation levels; typical U-values are calculated at below 0.3 W/m^{2}K. The most popular external finish is a render, as used in the Embletons' house, although various other claddings may be used.

Low-emissivity glass

'Low-e' glass has a thin coating applied to one surface. This coating is transparent to radiation with shorter wavelengths (heat from the sun, and visible light) but reflects longer wavelengths (heat from radiators and surfaces in the room), so reducing heat loss.

Argon fill

Argon gas is a better insulant than air and can be used to further improve the performance of double (or triple) glazing.

Mechanical ventilation with heat recovery

An MVHR system uses electric fans to extract air from the house via ducts hidden within the structure, and uses this stale air to warm incoming external air in a heat exchanger (often located in the loft or integral with the cooker hood). The fresh, warmed air is supplied to the internal spaces, maintaining a ventilation rate of 0.5 to 0.6 air changes per hour (ach), and ensuring an adequate supply of fresh air. The benefits of MVHR are savings in heating fuel costs (because less heat is required to warm incoming air), and good air quality. However, electricity is required to operate the fans, so although the systems save energy, overall fuel costs are not always reduced.

SAP

The government's Standard Assessment Procedure (SAP) is an energy rating which estimates a dwelling's energy efficiency on a scale of 1 (poor) to 100 (good). It is based on the annual fuel cost per square metre of floor area, for space and water heating, under a standard occupancy pattern.

CO_2

Carbon dioxide is the main greenhouse gas associated with global warming. Annual carbon dioxide emissions associated with the use of fuel in the house, including power station emissions, are quoted in kg per square metre of floor area (kg/m^2).

FURTHER INFORMATION

SUMMARY OF ADVICE

- Appoint design consultants who have experience of energy efficient design.
- Bring relevant Best Practice programme publications to the consultants' attention.
- Adopt an integrated approach to design, and aim to achieve a complementary package of building fabric, ventilation, heating and lighting systems specifications.
- Ensure that your house has a well-insulated envelope, with consistently high levels of insulation in the walls, roof and floors.
- Consider high-performance glazing such as double glazing with low-emissivity glass (possibly with argon-filled cavities), or triple glazing.
- Ensure that the building envelope and openings in it are well sealed, to prevent air infiltration, and provide controlled sources of fresh air.
- Specify good controls and an efficient and appropriate heating and hot water system which uses a low-cost fuel.
- Brief builders and tradespeople on the low energy aims of the project.

DOE ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following publications from the Department of the Environment's Best Practice programme are available from BRECSU Enquiries Bureau. Contact details are given below.

Good Practice Guides

73 Passive solar design

79 Low energy design

194 Building your own energy efficient house

General Information Leaflet

9 Domestic ventilation

\OTHER INFORMATION

Building Research Establishment. Thermal insulation: avoiding risks. BRE Report BR262. BRE, Garston, HMSO 1994.

Building Research Establishment. Environmental standard award – homes for a greener world. BRE Report BR278. London, CRC Publications, 1995. (CRC Publications, telephone 01923 664444)

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

For further information on:

Buildings-related projects contact:
Enquiries Bureau
BRECSU
BRE
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

Industrial projects contact:
Energy Efficiency Enquiries Bureau
ETSU
Harwell, Oxfordshire
OX11 0RA
Tel 01235 436747
Fax 01235 433066
E-mail etsuenq@aeat.co.uk

Internet **BRECSU** – http://www.bre.co.uk/bre/brecsu/
Internet **ETSU** – http://www.etsu.com/eebpp/home.htm

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting etc.